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A note on the estimation of nutrient value of cattle slurry using easily determined physical and chemical parameters

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The composition of cattle slurries can vary greatly due to factors such as farm management, meteorology, animal diet and housing system. Thus, when spread on land, the precise fertiliser value is usually unknown. In this study, 41 samples of cattle slurry from farms in Co. Wexford, were analysed for electrical conductivity (EC), pH, and for concentrations of dry matter (DM), total Kjeldahl N, total P and total K. Correlations between physico-chemical properties (pH, EC, DM) and nutrient concentration showed that DM and EC could be used to estimate nutrient concentration. Generally, DM was the best estimator of N (R^2 0.75) and P (R^2 0.82), while EC was the best estimator of K (R^2 0.73). EC was also highly correlated with N concentration (R^2 0.67). The proportion of variation accounted did not substantially increase when multiple regression was used.

Keywords: cattle slurry; nitrogen; phosphorus; physico-chemical properties; potassium

Introduction

Nutrient loss associated with agricultural practices has contributed directly or indirectly to the eutrophication of surface waters in Ireland (Tunney, Beeuwsma and Withers, 1997) and internationally (Stark and Richards, 2008). While agri-

cultural pollution remains a major threat, recent reports show that water quality in Ireland is improving (EPA, 2008). In recent years, environmental concerns have assumed greater importance and new laws and directives, designed to improve water quality (Provolo, 2005), that limit the

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amount of slurry that can be spread, have been put in place.

The sustainable use of slurry as a fertilizer must avoid the fast release of nutrients to reduce environmental impact (Vervoort *et al.*, 1998). However, the composition and availability of nutrients in slurry are highly variable (Van Kessel and Reeves, 2000). Laboratory analyses of animal slurries are often expensive and impractical. Therefore, when slurry is spread on land its fertilizer value is generally unknown, resulting in a risk of air, water and land pollution (European Environmental Agency, 2000).

Understanding the relationships between easily determined physico-chemical properties of slurry, such as pH, electrical conductivity (EC) or dry matter concentration (DM), and nutrient concentrations (N, P, K) can provide a basis for the estimation of the fertilizer value of slurry, thus facilitating its more efficient use in agriculture and reducing the potential risks to the environment (Scottford *et al.*, 1998b).

The objectives of this study were i) to examine the physico-chemical properties of cattle slurry using samples from farms in Co. Wexford, Ireland, and ii) to determine the relationships between some easily determined properties (pH, EC and DM) and the concentrations of N, P and K.

Material and Methods

Sampling and sample description

Forty-one slurry samples were taken from dairy ($n = 31$) and mixed dairy and beef ($n = 10$) farms in Co. Wexford, Ireland. Three samples were from outdoor storage tanks (lagoons), and all others from under floor storage tanks.

Some of the farms stored the slurry and dairy/yard washings together, while

others used separate tanks for each. Two sampling techniques were used, based on the degree of slurry homogenization on each farm. For non-homogeneous slurry (i.e., where slurry had not been recently agitated and a crust had formed on the surface), a tube sampler was used. This consisted of a 150 mm diameter rigid tube with a sealing mechanism at the bottom. The tube was inserted to the full depth of the tank and sealed to extract a column of slurry. This was to ensure, as far as possible, that the sample was representative of any stratified layers within the tank. For homogeneous slurry (i.e., tanks that were agitated), a bucket sampler was used to extract the sample mid-depth from each tank. Two samples were taken from each tank, then mixed, and a 1 L composite sample from each tank was stored at 4 °C pending analysis.

Laboratory analyses

Each sample was placed in a plastic beaker (4 L) and homogenized for 5 min under an extractor hood. EC, pH (standardized at 25 °C) and DM were determined on the full sample according to standard methods (APHA, 1998). Sub-samples were then taken for measurement of nutrient concentrations.

For DM determination, 100 g of fresh sample was dried in an oven at 105 °C for 24 h. Following sulphuric acid digestion of the fresh sample (Byrne, 1979), the N and P concentrations were determined colorimetrically on a continuous-flow analyser (Basson, Stanton and Bohmer, 1968), and K was measured by atomic absorption spectroscopy.

Statistical analysis

Pearson correlations were calculated between all of the measured variables. Both simple and multiple regression analyses were used to describe the relationships

between individual nutrient concentrations and the physico-chemical properties. For multiple regressions all three physico-chemical variables were included initially and a likelihood ratio test was used to compare models to ascertain if a multiple regression model showed significant improvement over the best simple regression model. All statistical analyses were conducted using SPSS (2002) software.

Results and Discussion

Chemical analysis

Summary statistics for the physico-chemical properties and nutrients are in Table 1. The high mean pH (7.3) observed favours N losses as gaseous ammonia from storage pits and tanks (Phillips *et al.*, 2000). The mean concentrations of N, P and K are similar to those reported for dairy slurry in other EU countries (Villar *et al.*, 1979; Scotford *et al.*, 1998a,b; Provolo and Martínez-Suller, 2007; Martínez-Suller, Azzellino and Provolo, 2008), and are comparable with those observed in Irish slurries by O'Bric (1991). However, the N and P concentrations are below those assumed in Ireland's Nitrates Directive regulations (Anonymous, 2009).

Simple correlations

The interrelationships among the physico-chemical and nutrient variables are shown in Table 2. Dry matter and EC were highly correlated ($P < 0.001$) with all of the

Table 2. Correlations among physical¹ (pH, EC, DM) and chemical (concentrations of N, P, K) properties of 41 cattle slurries

Variable	Variable				
	pH	EC	DM	N	P
EC	0.40*				
DM	-0.03	0.70***			
N	0.17	0.82***	0.86***		
P	-0.08	0.53***	0.90***	0.88***	
K	0.51**	0.85***	0.61***	0.66***	0.45**

¹EC = electrical conductivity; DM = dry matter.

nutrients. However, K was the only nutrient significantly correlated with pH ($P < 0.01$). Stevens, O'Bric and Carton (1995) also observed high correlations between EC and both N and K concentrations of pig and cattle slurries, something confirmed later by Bellotti (1997).

In a number of studies (Piccinini and Bortone, 1991; Stevens *et al.*, 1995; Scotford *et al.*, 1998a,b; Moral *et al.*, 2005), the concentration of P has shown higher correlations with density, DM concentration or settleable solids than with EC in contrast to the significant correlation between P and EC found in the current study (Table 2). A similar result was observed in a study involving 22 dairy farms in Italy (Martínez-Suller *et al.*, 2008).

Selected simple and multiple regression equations for nutrient estimation

Simple and multiple regression equations to best predict fertilizer nutrient con-

Table 1. Summary statistics for measurements on 41 cattle slurries

Variable ¹	Mean	Median	Maximum	Minimum	s.d.	CV (%)
pH	7.3	7.3	7.8	6.8	0.2	2.9
EC (S/m)	1.43	1.60	2.33	4.1	4.9	34
DM (g/kg)	62.7	65.1	97.3	5.7	20.7	33
N (kg/m ³)	3.43	3.27	7.03	0.36	1.4	41
P (kg/m ³)	0.56	0.61	1.13	0.04	0.25	44
K (kg/m ³)	4.41	4.91	7.75	0.94	2.04	46

¹EC = electrical conductivity; DM = dry matter.

Table 3. Simple and multiple regression equations for predicting nutrient concentration (kg/m³) of cattle slurry from the pH, electrical conductivity (EC; S/m) and dry matter concentration (DM; g/kg)

Nutrient	Equation	Coefficient of determination	Residual s.d.
Simple regression equations			
N	0.06DM – 0.22	0.75***	0.71
P	0.01DM – 0.11	0.82***	0.11
K	3.4EC – 0.73	0.73***	1.64
Multiple regression equations			
N	0.04DM + 1.2EC – 0.70	0.83***	0.58
P	0.013DM – 0.1EC – 0.07	0.84***	0.10
K	3.2EC + 2.00pH – 14.75	0.75***	1.02

centration are shown in Table 3. The best single-variable relationship for N concentration was observed with DM. A number of studies (Tunney, 1979; Villar *et al.*, 1979; Scotford *et al.*, 1998a; Provololo and Martínez-Suller, 2007) have identified P as the most difficult nutrient to estimate in slurry. Nevertheless, in this study the equation relating P to DM had the highest coefficient of determination for single-variable models among the three nutrients (R^2 0.82, $P < 0.001$). Electrical conductivity was the best single-variable predictor of K concentration, which is in agreement with other studies (Bellotti, 1997; Scotford *et al.*, 1998a,b; Provololo and Martínez-Suller, 2007).

The multiple regression equations that significantly improved the prediction of nutrient composition were all two-variable equations and are also shown in Table 3. For N and P, DM and EC were the predictors involved, while for K, EC and pH were the significant independent variables in the equations. While for all three nutrients, the proportion of variation accounted for was not substantially increased by multiple regression, compared with the best single-variable predictor, the likelihood ratio tests indicated significant improvement. Nitrogen showed the greatest significant improvement ($P < 0.001$) from multiple regression, with the residual stan-

dard deviation being reduced from 0.71 to 0.58. The improvements for P and K were less significant ($P < 0.05$), with only marginal reductions in the residual variation (Table 3). The highest proportion of variation accounted for was for P (84%), but was only marginally higher than for N and the gain from multiple regression was small. The very small improvement from multiple regression in the case of P and K was probably due to the fact that one of the explanatory variables, EC for P, and pH for K, had a relatively low coefficient of determination in the corresponding simple regression (see Table 2).

As simple laboratory procedures, DM and EC are rapid and cheap estimators of the nutrient concentration of slurry compared to standard laboratory chemical determination methods. Furthermore, EC has the added potential benefit of being usable *in situ* (slurry tank or spreading tank) to estimate N and K concentrations. Using a larger number of samples of different types of slurry with seasonal differences could further refine these findings.

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